Chapter 3. Water Quality

INTRODUCTION

The City of San Diego monitors water quality along the shoreline and in offshore ocean waters for the region surrounding the Point Loma Ocean Outfall (PLOO). This aspect of the City's ocean monitoring program is designed to assess general oceanographic conditions, evaluate patterns in movement and dispersal of the PLOO wastewater plume, and monitor compliance with water contact standards as defined in the 2001 California Ocean Plan (COP). Results of all sampling and analyses, including COP compliance summaries, are submitted to the San Diego Regional Water Quality Control Board in the form of monthly receiving waters monitoring reports. Densities of fecal indicator bacteria (FIB), including total coliforms, fecal coliforms, and enterococcus, are measured and evaluated along with data on local oceanographic conditions (see Chapter 2) to provide information about the movement and dispersion of wastewater discharged to the Pacific Ocean through the outfall. Evaluation of these data may also help to identify other point or non-point sources of bacterial contamination (e.g., outflows from rivers or bays, surface runoff from local watersheds). This chapter summarizes and interprets patterns in seawater FIB concentrations collected for the Point Loma region during 2009.

Materials and Methods

Field Sampling

Seawater samples for bacteriological analyses were collected at a total of 52 shore, kelp bed, or other offshore monitoring sites during 2009 (Figure 3.1). Sampling was performed weekly at eight shore stations (i.e., stations D4, D5, and D7–D12) to monitor FIB concentrations in waters adjacent to public beaches and to evaluate compliance with the COP water contact standards (see Box 3.1). Eight stations located in nearshore waters within the Point Loma kelp forest were also monitored weekly to assess water quality conditions and COP compliance in areas used for recreational activities such as SCUBA diving, surfing, fishing, and kayaking. These include stations C4, C5, and C6 located near the inner edge of the kelp bed along the 9-m depth contour, and stations A1, A6, A7, C7, and C8 located near the outer edge of the kelp bed along the 18-m depth contour.

An additional 36 stations located further offshore were sampled in order to monitor FIB levels in these deeper waters and estimate dispersion of the wastewater plume. These offshore stations are arranged in a grid surrounding the discharge site along or adjacent to the 18, 60, 80, and 98-m depth contours (Figure 3.1). The stations were sampled quarterly during the months of February, May, August and November, with each survey occurring

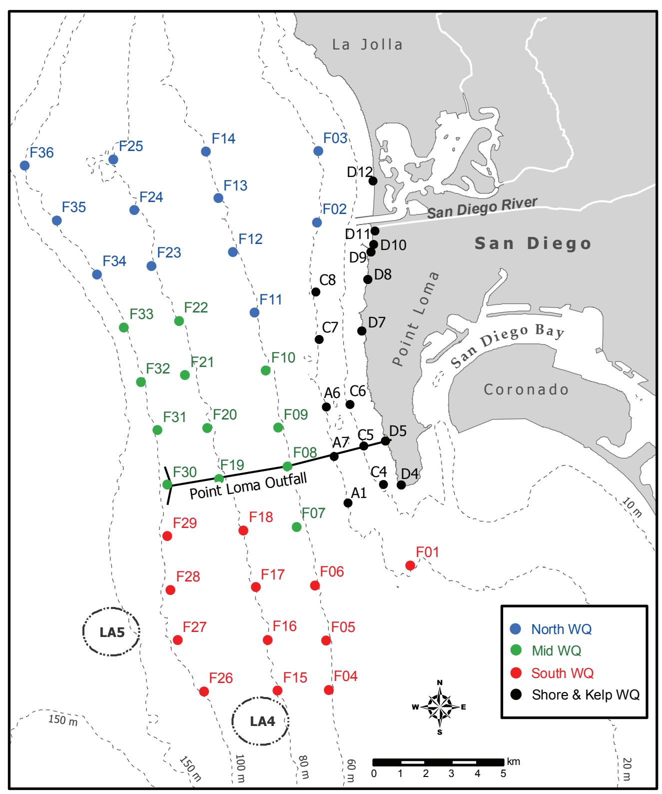

Figure 3.1
Water quality monitoring stations for the Point Loma Ocean Outfall Monitoring Program.

Box 3.1

Bacteriological compliance standards for water contact areas, 2001 California Ocean Plan (SWRCB 2001). CFU = colony forming units.

(a) *30-day Total Coliform Standard* — no more than 20% of the samples at a given station in any 30-day period may exceed a concentration of 1000 CFU/100 mL.

(b) *10,000 Total Coliform Standard* — no single sample, when verified by a repeat sample collected within 48 hrs, may exceed a concentration of 10,000 CFU/100 mL.

(c) *60-day Fecal Coliform Standard* — no more than 10% of the samples at a given station in any 60-day period may exceed a concentration of 400 CFU/100 mL.

(d) *30-day Fecal Geometric Mean Standard* — the geometric mean of the fecal coliform concentration at any given station in any 30-day period may not exceed 200 CFU/100 mL, based on no fewer than five samples.

over three days. For sampling and analysis purposes, these 36 stations are grouped as follows: (a) stations F02, F03, F11–F14, F23–F25, and F34–F36 comprise the 12 northern water quality (North WQ) sites; (b) stations F07–F10, F19–F22, and F30–F33 comprise the 12 mid-region water quality (Mid-WQ) sites; (c) stations F01, F04–F06, F15–F18, and F26–F29 comprise the 12 southern water quality (South WQ) sites. All stations within each of these three groups are sampled on a single day during each quarterly survey. See Appendix A.1 for the specific dates these surveys were conducted in 2009.

In addition, three other stations (A11, A13, A17) located seaward of the kelp bed were sampled voluntarily as part of the weekly sampling to monitor water quality near the original PLOO discharge site (i.e., pre-1994). Analysis of data for these three stations is not included herein, but has been reported elsewhere (see City of San Diego 2009a, 2010a).

Seawater samples for the shore stations were collected from the surf zone in sterile 250-mL bottles. Additionally, visual observations of water color,

Table 3.1

Depths at which seawater samples are collected for bacteriological analysis at the PLOO kelp bed and offshore stations.

Station Contour	Sample Depth (m)								
	1	3	9	12	18	25	60	80	98
Kelp Bed									
9 m	x	x	x						
18 m	x			x	x				
Offshore									
18 m	x			x	x				
60 m	x					x	x		
80 m	x					x	x	x	
98 m	x					x	x	x	x

surf height, human or animal activity, and weather conditions were recorded at the time of collection. The samples were then transported on blue ice to the City of San Diego's Marine Microbiology Laboratory (CSDMML) where they were analyzed to determine FIB concentrations (i.e., total coliform, fecal coliform, and enterococcus bacteria).

Seawater samples for the kelp bed and offshore stations were collected at 3–5 discrete depths per site dependent upon station depth (see Table 3.1) and analyzed for the above FIBs. These samples were collected using either an array of Van Dorn bottles or a rosette sampler fitted with Niskin bottles. Aliquots for total coliform, fecal coliform and enterococcus analysis were drawn into appropriate sample containers. These samples were refrigerated onboard ship and then transported to the CSDMML for processing and analysis. Visual observations of weather and sea conditions, as well as human or animal activity were also recorded at the time of sampling.

Laboratory Analyses and Data Treatment

The CSDMML follows guidelines issued by the United States Environmental Protection Agency (U. S. EPA) Water Quality Office, Water Hygiene Division, and the California State Department of Health Services (CDHS) Environmental Laboratory

Accreditation Program (ELAP) with respect to sampling and analytical procedures (Bordner et al. 1978, APHA 1998). These guidelines dictate holding times, filtration techniques, procedures for counting colonies of indicator bacteria, calculation and interpretation of results, data verification and reporting. For example, all bacterial analyses were performed within 8 hours of sample collection and conformed to standard membrane filtration techniques (see APHA 1998). In addition, plates with FIB counts above or below ideal counting ranges were given greater than (>), less than (<), or estimated (e) qualifiers. However, these qualifiers were excluded and the counts treated as discrete values when calculating means and in determining compliance with COP standards. Further, routine quality assurance tests were performed on seawater samples to ensure that sampling variability did not exceed acceptable limits. Duplicate and split bacteriological samples were processed according to method requirements to measure intrasample and inter-analyst variability, respectively. Results of these procedures for 2009 were reported in City of San Diego (2010b).

Bacteriological benchmarks defined in the 2001 COP and Assembly Bill 411 (AB 411) were used as reference points to distinguish elevated FIB values in receiving water samples discussed in this report. These benchmarks are: (a) >1000 CFU/100 mL for total coliforms; (b) >400 CFU/100 mL for fecal coliforms; (c) >104 CFU/100 mL for enterococcus. Data were summarized for analysis by counting the number of samples with FIB levels higher than one or more of these benchmarks. Furthermore, any water sample with total coliforms ≥1000 CFU/100 mL and a fecal:total ratio ≥0.1 was considered representative of contaminated waters (see CDHS 2000). This condition is referred to as the Fecal:Total Ratio (FTR) criterion herein.

Results and Discussion

Shore Stations

As in previous years, concentrations of indicator bacteria were generally low along the Point Loma shoreline in 2009. Monthly FIB densities at the individual shore stations averaged about 2–4031 CFU/100 mL for total coliforms, 2–194 CFU/100 mL for fecal coliforms, and 2–2841 CFU/100 mL for enterococcus (Appendix B.1). Out of the 480 discrete seawater samples collected during 2009, none met the FTR criterion for contaminated waters. In addition, 14 of the 20 samples with elevated FIBs were collected during the wet season during or shortly after rainfall events (Table 3.2), which occurred primarily in January, February, and December (Appendix B.2). Of these 14 samples, eight had elevated densities of just enterococcus, four had elevated densities of just total coliforms, one had elevated densities of both total coliforms and enterococcus, and one had elevated densities of both fecal coliforms and enterococcus.

The other six samples with elevated FIB densities occurred during periods without any measurable rainfall (Table 3.2). These included one sample collected at station D4 in October, four samples collected at station D8 during June and October, and one sample collected at station D12 in July (Appendix B.2). Four of these samples contained elevated levels of enterococcus only, while one had elevated densities of fecal coliforms and entercoccus, and one had elevated densities of just

Table 3.2
The number of samples with elevated FIBs collected at PLOO shore stations during 2009. Wet season = January–April and November–December; dry season = May–October; *n* = total number of samples. Rain data are from Lindbergh Field, San Diego, CA. Stations are listed from north to south from top to bottom.

	Season		
Station	Wet	Dry	Total
D12	1	1	2
D11	3	0	3
D10	2	0	2
D9	1	0	1
D8	5	4	9
D7	2	0	2
D5	0	0	0
D4	0	1	1
Rain (in)	5.29	0.21	5.5
Total	14	6	20
n	240	240	480

Table 3.3

Summary of FIB densities (CFU/100 mL) at PLOO kelp bed stations in 2009. Data are expressed as means for all stations along each depth contour by month; *n* = total number of samples per month.

Assay	Contour	*n*	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	9 m	45	10	5	4	3	5	2	2	3	8	4	9	45
	18 m	75	7	6	8	3	7	3	2	3	19	4	5	903
Fecal	9 m	45	2	2	2	2	2	2	2	2	2	2	2	2
	18 m	75	2	2	2	2	3	2	2	2	2	2	2	3
Entero	9 m	45	2	2	2	2	4	8	2	12	6	4	15	7
	18 m	75	2	4	2	2	25	503	7	10	4	4	3	15

total coliforms. A possible source of contamination at station D8 is a tidally influenced storm drain (see Martin and Gruber 2005, Griffith et al. 2010), which has been suggested previously as a likely cause of high FIB counts in the area during dry periods (see City of San Diego 2005–2008, 2009b). Other sources that may contribute to bacterial contamination at station D8, as well as at stations D4 and D12, include beach wrack (i.e., decaying kelp and seagrass) and shorebirds (see Oshiro and Fujioka 1995, Arvanitidou et al. 2001, Grant et al. 2001, Griffith et al. 2010), all of which are commonly present during sampling times.

Kelp Bed Stations

Concentrations of indicator bacteria were also generally low at the eight kelp bed stations in 2009. For example, monthly FIB densities at these stations averaged about 2–903 CFU/100 mL for total coliforms, 2–3 CFU/100 mL for fecal coliforms, and 2–503 CFU/100 mL for enterococcus (Table 3.3). Of the 1440 seawater samples collected from these sites during the year, only 25 (1.7%) had elevated FIB concentrations, none of which exceeded the FTR criterion for contaminated waters (Appendix B.3). Eleven of the 25 samples with elevated FIBs were collected during the wet season and were likely associated with rainfall events (Table 3.4). Of these, eight samples had elevated counts of total coliforms, seven had elevated enterococcus levels, and none had elevated levels of fecal coliforms.

In contrast to previous years when very few seawater samples with elevated FIBs occurred in the Point Loma kelp forest during the dry season (e.g., see City of San Diego 2009b), 14 samples were collected at the kelp stations between May and August during 2009 (Table 3.4, Appendix B.3). However, these samples were collected only at stations A1, A6, A7, C7 and C8 located near the outer edge of the kelp bed. Additionally, these samples only had elevated levels of enterococcus, some of which were unusually high up to 12,000 CFU/100 mL (see Appendix B.3). Potential sources for these elevated enterococcus densities are unclear.

Offshore Stations

Average FIB densities per depth contour for the 36 offshore stations sampled quarterly during 2009 are presented in Table 3.5. Seawater samples from the shallowest 18-m stations had very low concentrations of total coliforms, fecal coliforms, and enterococcus averaging ≤14 CFU/100 mL during each survey. In contrast, FIB densities were typically higher at the deeper stations along the 60, 80, and 98-m transects, averaging up to 870 CFU/100 mL for totals, 384 CFU/100 mL for fecals, and 32 CFU/100 mL for enterococcus. All of the highest mean FIB values occurred during May at the 80-m stations. Overall, these average FIB values were lower in 2009 than during the previous five years (see City of San Diego 2005–2008, 2009b). This recent decrease in FIB densities may be associated with the implementation of chlorination and partial disinfection of PLOO effluent, which began near the end of 2008 and continues to present.

Of the 564 seawater samples collected at the offshore stations during the year, only 41 (~7.3%) contained elevated FIB densities (see Appendix B.4).

Table 3.4

The number of samples with elevated FIBs collected at PLOO kelp bed stations during 2009. Wet season = January–April and November–December; dry season = May–October; *n* = total number of samples. Rain data are from Lindbergh Field, San Diego, CA. Stations are listed from north to south from top to bottom by depth contour.

	Season		
Station	**Wet**	**Dry**	**Total**
18-m Depth Contour			
A6	2	4	6
A7	3	4	7
A1	2	2	4
C8	1	3	4
C7	1	1	2
9-m Depth Contour			
C6	0	0	0
C5	0	0	0
C4	2	0	2
Rain (in)	5.29	0.21	5.5
Total	11	14	25
n	720	720	1440

Table 3.5

Summary of FIB densities (CFU/100 mL) at PLOO offshore stations in 2009. Data for each quarterly survey are expressed as means for all stations along each depth contour; *n* = total number of samples per survey.

Assay	Contour	*n*	Feb	May	Aug	Nov
Total	18 m	9	9	2	4	14
	60 m	33	134	657	45	12
	80 m	44	340	870	488	122
	98 m	55	99	851	567	746
Fecal	18 m	9	2	2	2	4
	60 m	33	17	127	7	3
	80 m	44	55	384	92	15
	98 m	55	13	314	106	231
Entero	18 m	9	2	2	2	5
	60 m	33	5	14	2	3
	80 m	44	8	32	17	7
	98 m	55	3	20	10	19

Individually, 39 samples had total coliform concentrations >1000 CFU/100 mL, 24 samples had fecal coliforms >400 CFU/100 mL, and 12 samples had enterococcus densities > 104 CFU/100 mL. Twenty-two of these samples had elevated levels of all three FIB types ($n=12$) or just total and fecal coliforms ($n=10$). A total of 38 samples (~6.7%) met the FTR criterion for contaminated seawater, which may be indicative of the PLOO wastefield; these included 33 of the samples with elevated totals plus five additional samples with totals equal to, but not exceeding 1000 CFU/100 mL. Figure 3.2 provides a comparison of the proportion of samples with elevated FIBs to those indicative of contaminated waters for each depth contour.

Patterns in the distribution of samples that exceeded the FTR criterion each quarter were evaluated to estimate possible dispersion of the PLOO wastefield during these surveys. All but one of these samples were collected from depths of 60 m or greater (see Figure 3.3). If these FIB counts and distributions do reflect the dispersion of contaminated waters associated with the wastefield, the results suggest that the wastewater plume remained restricted to relatively deep waters throughout the year. This conclusion is consistent with remote sensing observations that provided no evidence of the plume reaching surface waters in 2009 (see Svejkovsky 2010). Additional comparisons also suggest that wastewater dispersion and plume transport varied both within and between survey periods (e.g., Figure 3.3). For example, the May and August surveys indicate a mixed northern and southern dispersion of the plume along the 60, 80 and 98-m depth contours. In contrast, the plume appeared to disperse primarily to the south in February and to the north in November. However, it should be noted that the offshore samples are collected over multiple days, and ocean conditions such as current direction can change daily (or even within a day). Even so, these results appear to align with preliminary current data for the region (e.g., Parnell and Rasmussen 2010).

California Ocean Plan Compliance

Compliance with the bacterial water contact standards specified in the 2001 COP (see Box 3.1) was very high in 2009 for the shore and kelp bed stations sampled off Point Loma (see Appendices B.5, B.6). For example, all of the kelp stations and six of the eight shore stations were in complete compliance with all four of the COP standards throughout the year. Only shore stations D8 and D11 fell below

100% compliance, with each of the exceedances occurring during winter "wet season" months. For example, the 30-day total coliform standard was exceeded at station D8 in January and at station D11 during February and March, resulting in 95% and 92% overall compliance with this standard, respectively. Station D11 also exceeded the 10,000 total coliform standard once in February, as well as the 60-day fecal coliform standard the following December. Both D8 and D11 were 100% compliant with the 30-day fecal geometric mean standard.

Summary and Conclusions

There was no evidence that wastewater discharged to the ocean via the PLOO reached shoreline or near-shore recreational waters in 2009. Although elevated FIB densities were occasionally detected along the shoreline and at the kelp bed stations throughout the year, concentrations of these bacteria tended to be relatively low overall. In fact, none of the seawater samples collected met the FTR criteria for contamination and only two samples with elevated levels of fecal coliform bacteria were collected in 2009 at these stations. In general, elevated FIB densities at shore and kelp bed stations were limited to instances when the source of contamination was likely associated with rainfall, seabirds, heavy recreational use, or decaying plant material (i.e., kelp and surfgrass). For example, most of the elevated bacterial densities occurred during February and December, which were some of the wettest months of the year. For these reasons, seawater samples from all of the kelp bed stations and all but two of the shore stations were 100% compliant with the four COP standards. The few exceedences for shore stations D8 and D11 corresponded to rain events or other sources of contamination unrelated to the PLOO discharge.

Previous analyses of water quality data for the region have indicated that the PLOO wastefield has typically remained well offshore and submerged in deep waters since the extension of the outfall was completed in late 1993 (e.g., City of San Diego 2007, 2008, 2009b). This pattern remained true for 2009

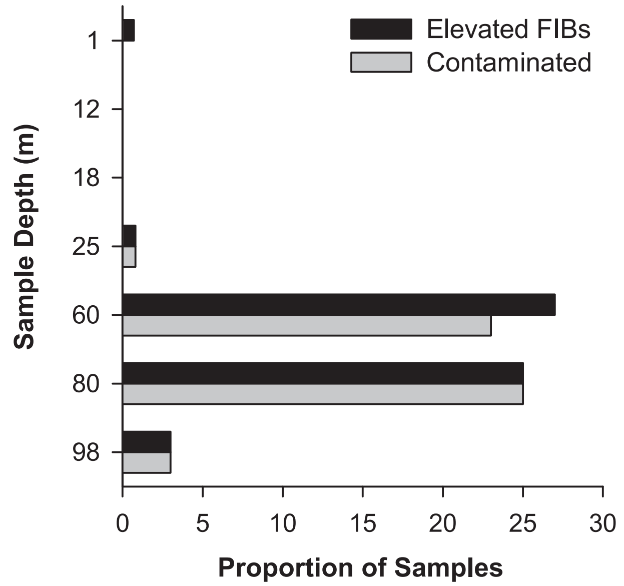

Figure 3.2
Summary of FIBs by depth for PLOO offshore stations in 2009. Data are expressed as the proportion of samples with elevated FIB densities and the proportion of samples that met FTR criterion indicative of contaminated seawater.

with evidence of the wastewater plume (i.e., samples with elevated FIBs and exceedences of the FTR criterion) being restricted to depths of 60 m or below in offshore waters. Moreover, no visual evidence of the plume surfacing was detected in aerial or satellite imagery during 2009 (Svejkovsky 2010). The 98-m depth of the discharge site may be the dominant factor that inhibits the plume from reaching surface waters. For example, wastewater released into these deep, cold and dense waters does not appear to mix with the top 25 m of the water column. Finally, it appears that not only is the plume from the PLOO being trapped below the thermocline, but now that effluent is undergoing chlorination prior to discharge, densities of indicator bacteria in local receiving waters have dropped substantially.

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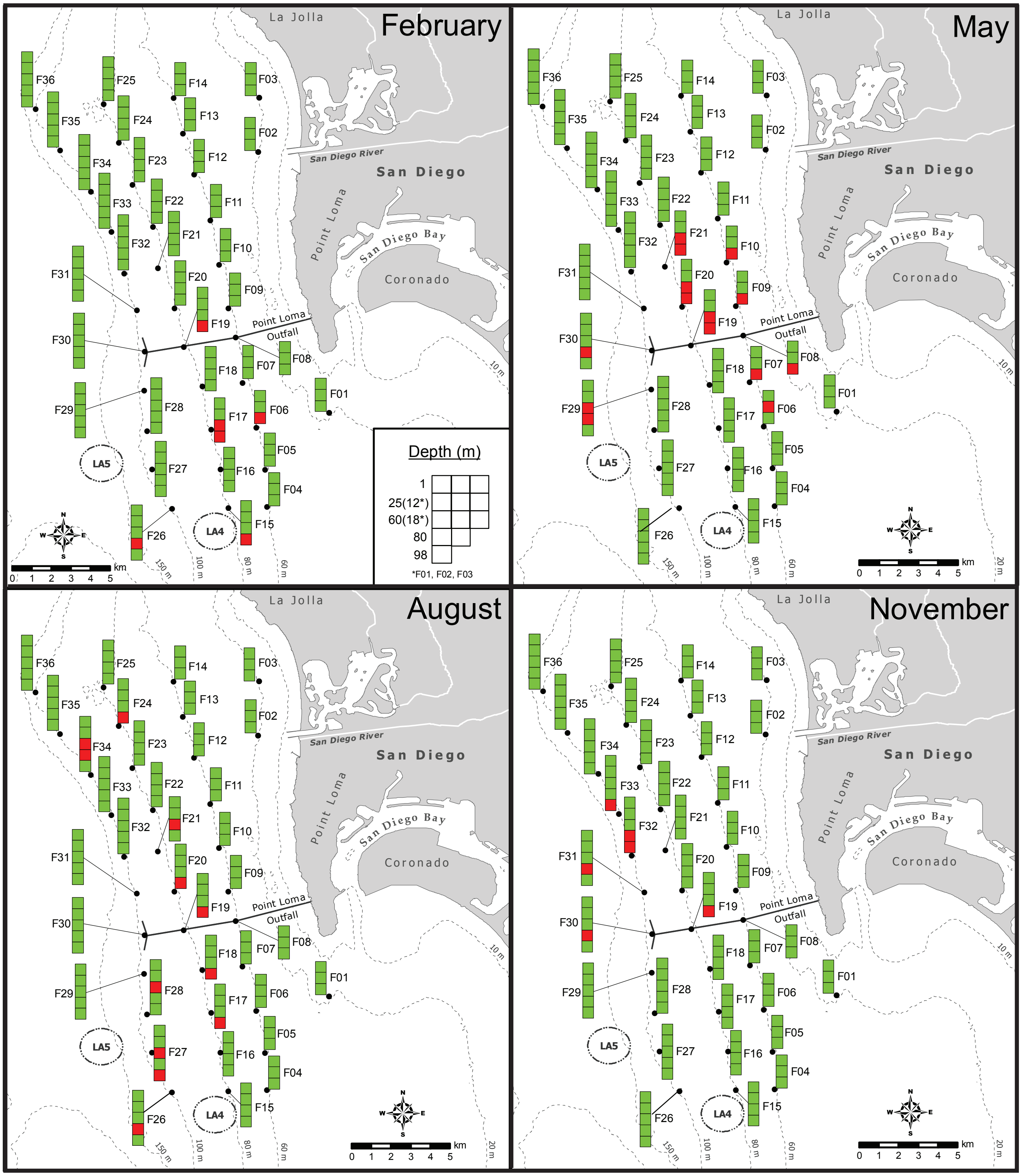

Figure 3.3
Distribution of seawater samples collected during the PLOO quarterly surveys in 2009 that exceeded (red squares) or did not exceed (green squares) the FTR criterion indicative of contaminanted waters. See text and Appendix A.1 for sampling details.

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